Tandem acoustic modeling: Neural nets for mainstream ASR?

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Outline

1. **Tandem acoustic modeling**
2. **Inside Tandem systems: What's going on?**
3. **Future directions**

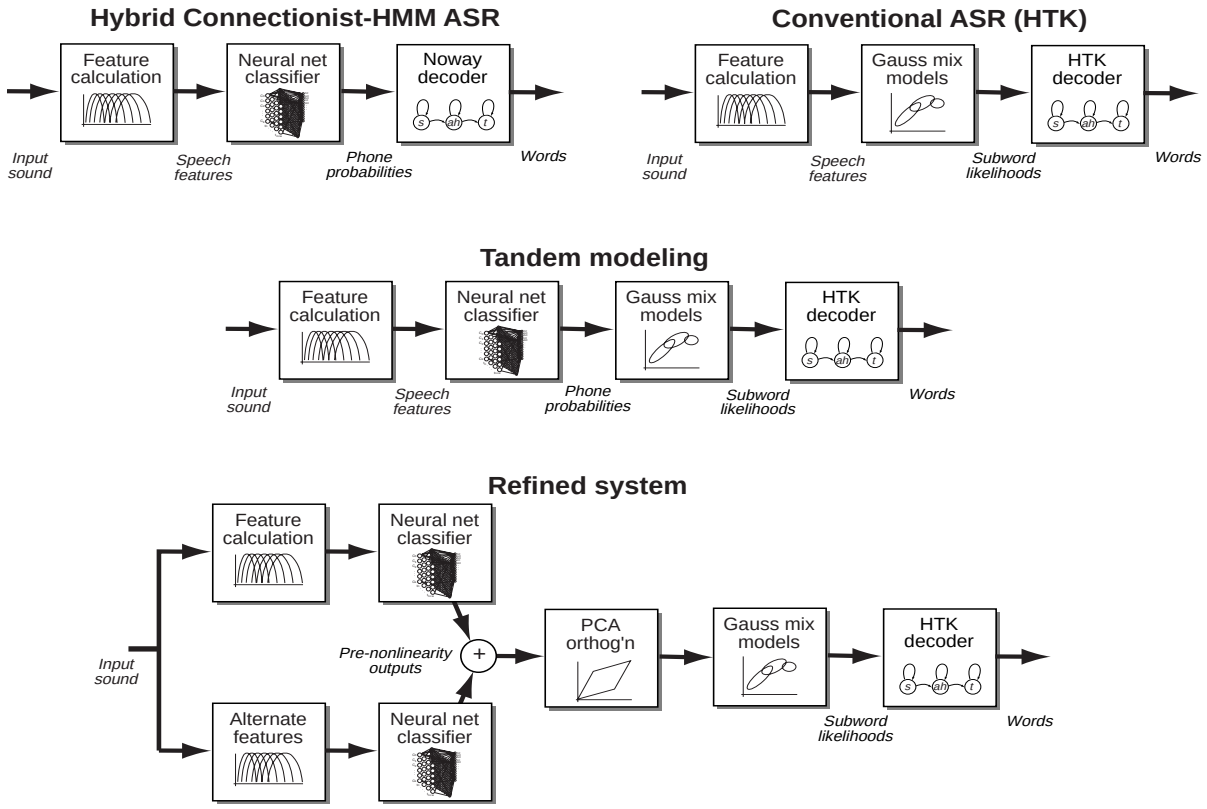
1 Tandem acoustic modeling

- **ETSI Aurora 'noisy digits' evaluation**
  - new features (for distributed speech recognition)
  - Gaussian mixture HTK back-end provided
- **How to use hybrid-connectionist tricks? (multistream posterior combination etc.)**

→ **Use posterior *outputs* as *features* for HTK...**

= ***Tandem* connection of two large statistical models: Neural Net (NN) and Gaussian Mixture (GMM)**

The Tandem structure



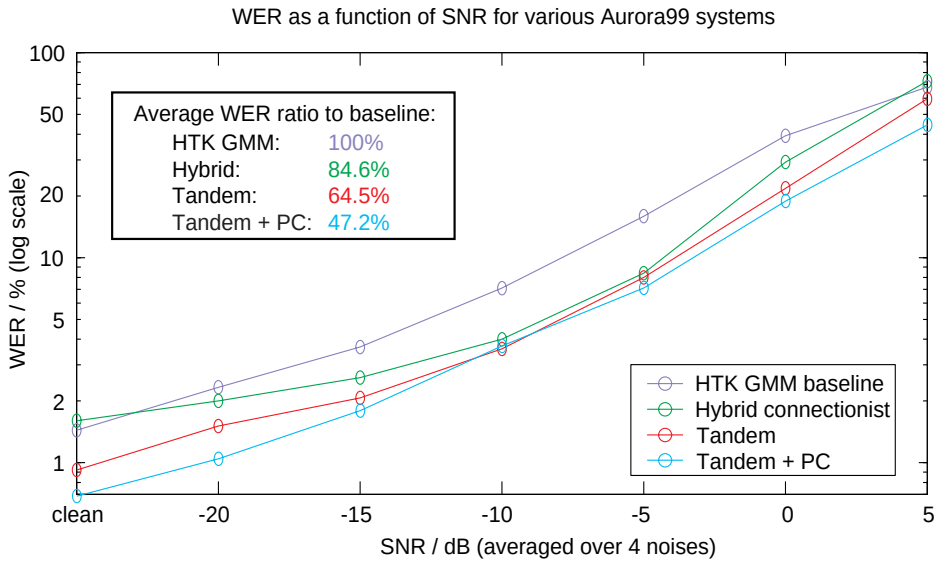
- **Better results when posteriors are made more 'Gaussian'**
- **Tandem allows posterior combination for HTK**

Training a tandem model

- **Tandem modeling uses two feature-spaces**
  - NN estimates phone posteriors (discriminant)
  - GMM models subword likelihoods (distributions)
- **Training procedure**
  - NN trained (backprop) on base features to forced-alignment phone targets
  - GMM trained on modified NN outputs via EM to maximise subword model likelihoods
  - HTK backend knows *nothing* of phone models
- **Decoupled (good) but sequential**
- **Training sets?**
  - can use same for both - learning different info
  - could use different - for cross-task robustness

Tandem system results

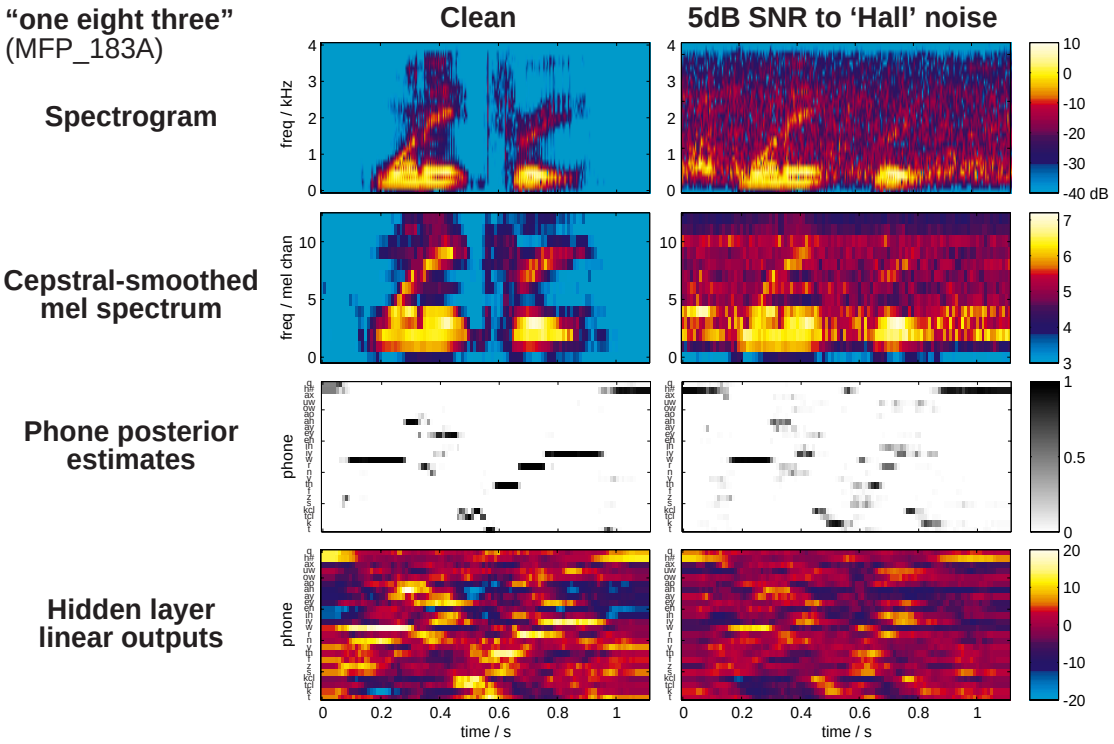
- **It works very well:**



System-features	*Avg. WER 20-0 dB*	*Baseline WER ratio*
HTK-mfcc	13.7%	100%
Neural net-mfcc	9.3%	84.5%
Tandem-mfcc	7.4%	64.5%
Tandem-msg+plp	**6.4%**	**47.2%**

2 Inside Tandem systems: What's going on?

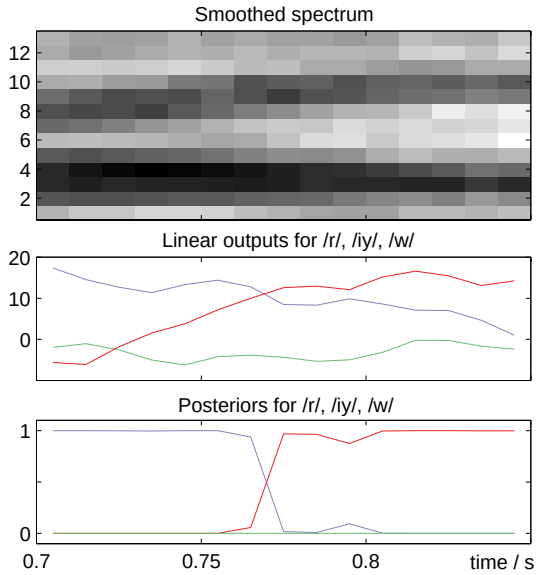
- **Visualizations of the net outputs**



- **Neural net normalizes away noise**

Feature space ‘magnification’

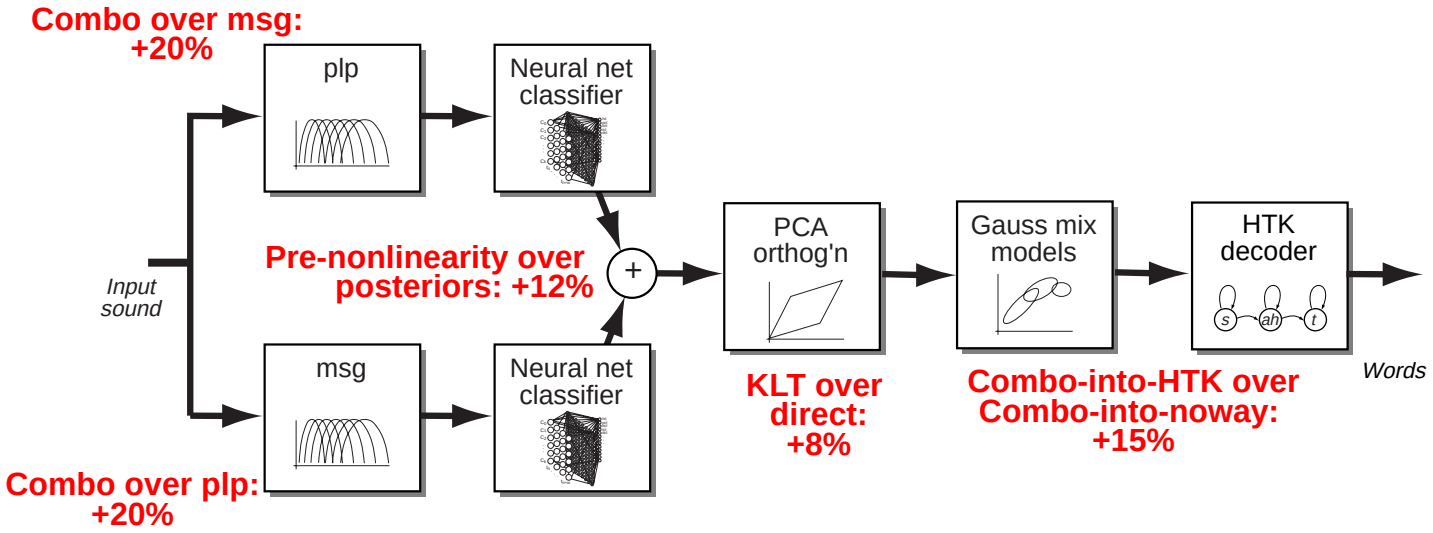
- **Neural net performs a nonlinear remapping of the feature space**



  - small changes across critical boundaries result in large output changes

Relative contributions

- **Approx relative impact on baseline WER ratio for different component:**

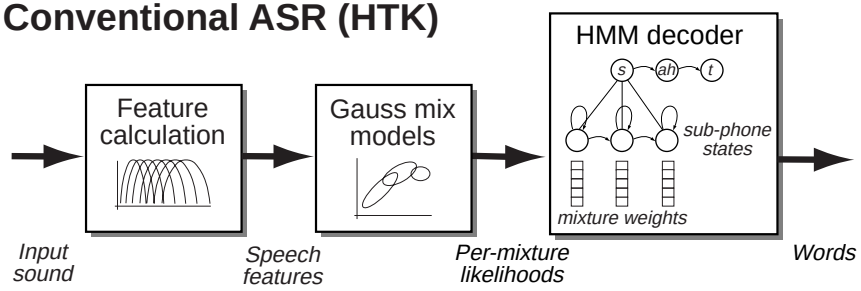


Tandem combo over HTK mfcc baseline: +53%

Omitting the GMMs

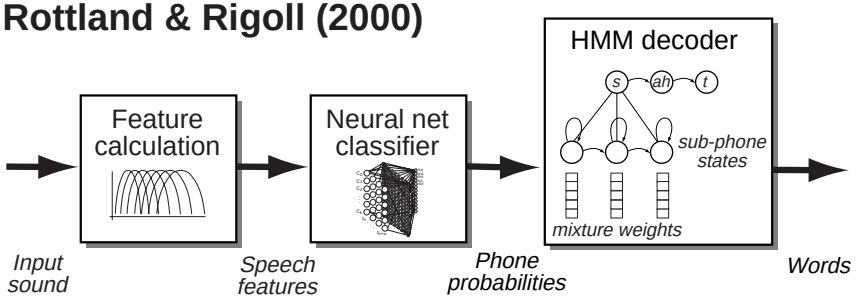
- **"Tied posteriors" (Rottland & Rigoll, ICASSP):**

Conventional ASR (HTK)



- EM training of GMM and HMM mixture weights

Rottland & Rigoll (2000)



- only mixture weights trained by EM

System	*WSJ0 WER*
Hybrid baseline	15.8%
"Tied posteriors"	9.4%

3 Discussion

- **Key limitation: task-specific**
  - NN is *not* like features (it's part of the trained system)
- **Aurora1999 was a 'matched condition' task**
  - same noises added in training and test
  - Aurora2000 has mismatched conditions
  - Tandem modeling works just as well
- **How to relax specificity?**
  - train on alternative task?
  - use articulatory targets

Future developments

- **How to optimize NN for this structure?**
  - integrated training...previous work
  - HMM states as targets?
- **Understanding the gains**
  - better analysis of each piece's contribution
  - strengths of different modeling approaches
  - effects of model/training set size variation
  - "tied posteriors"?
- **Other speech corpora**
  - need both NN and GMM systems...
  - Switchboard is next goal